NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Net-Zero Energy Commercial Buildings At NREL:
Research and Practice

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NREL

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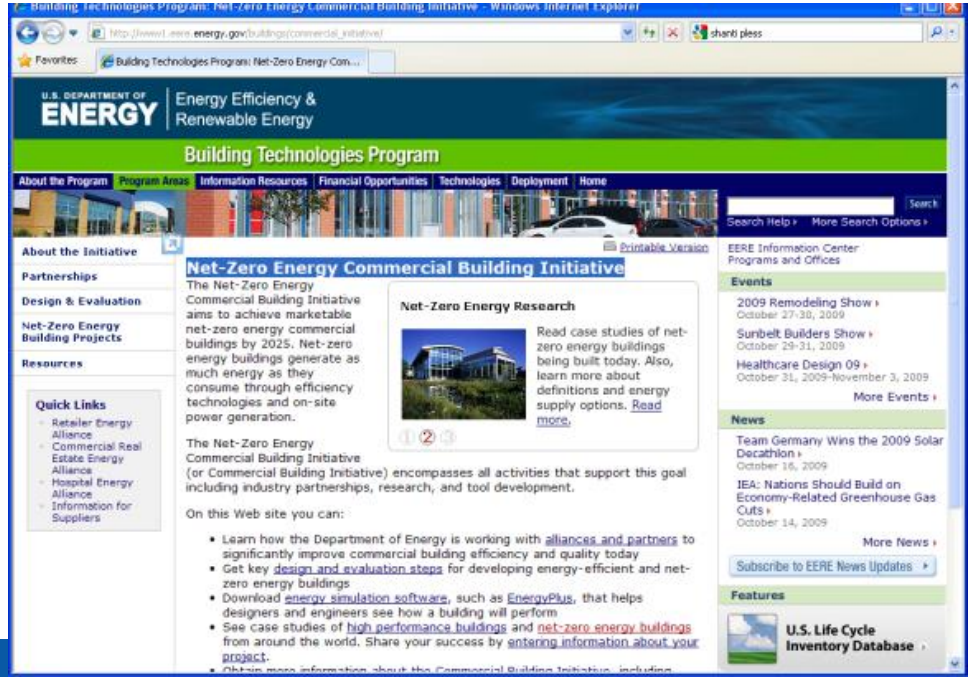
Advanced Commercial Building Research at NREL

DOE EERE funded applied Research RD+D to change the industry and move the market

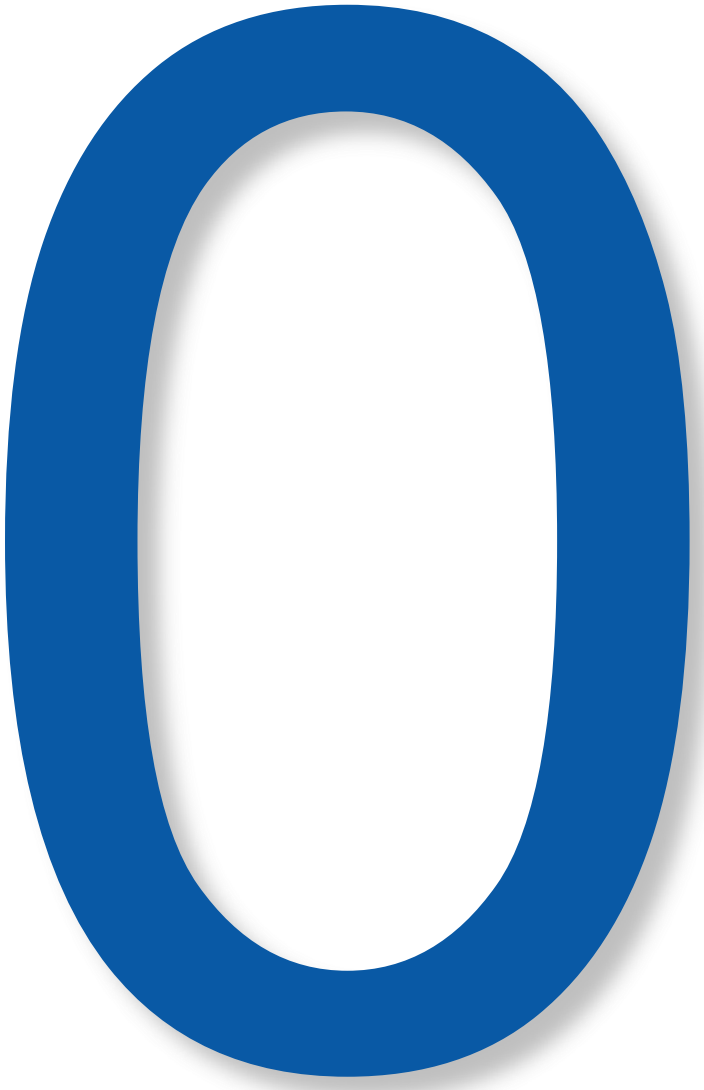
- Commercial Building Energy Alliances (CBEA)
- Commercial Building Partnerships (CBP)
- Net Zero Energy Buildings (ZEB)
  - DOE's Net Zero Energy Commercial Building's Initiative
- Technical Support Documents & Advanced Energy Design Guides
- HVAC Test Facility
- Opt-E-Plus
- EnergyPlus
- Open Studio



The Future of Zero Energy Buildings

- The DOE Net-Zero Energy Commercial Building Initiative aims to achieve marketable net-zero energy commercial buildings by 2025
- ASHRAE Vision 2020
- AIA 2030 Challenge
- California Public Utilities Commission ZEB Action Plan
  - All new residential ZEB by 2020
  - All new commercial ZEB by 2030
- EU ZEB requirement by 2019
  - International Energy Agency ZEB Definitions Task
- All Federal Buildings ZEB by 2030
  - October 2009 Executive Order
  - Beginning in 2020 all new Federal buildings that enter the planning process are designed to achieve zero-net-energy by 2030

www.commercialbuildings.energy.gov



What are [Net] Zero Energy Buildings?

- Conceptually, a building that has no adverse energy [or environmental] impact [because of its operation]
- ZERO is not easy to define!
- Not easy to design to if not well defined
  - Disconnect all utility interfaces?
  - What is the energy performance metric?
  - Net energy transfer across boundary?
  - **Where is the boundary?**

Guiding Concepts

- Buildings can meet all of their energy needs from renewable sources
- Demand side first, then supply side
- Net zero using grid for energy balance
- Prioritize renewable energy options
  - Within Footprint
  - On-site

- Lots of Room for Interpretation…

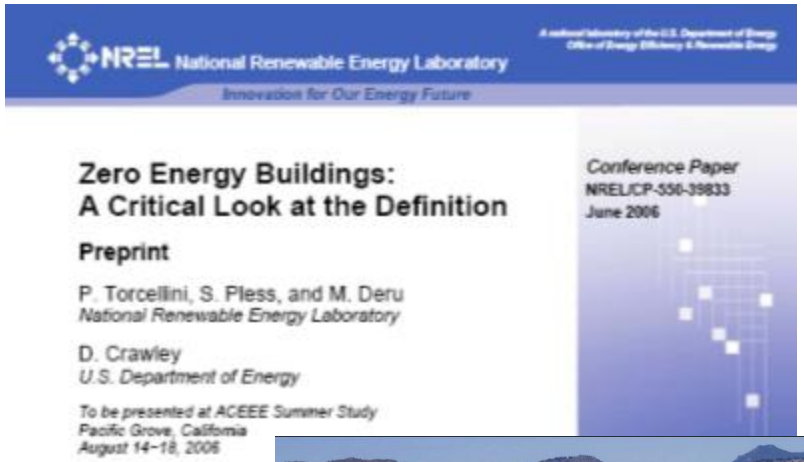
Definitions of NZEB's

Net Zero Site Energy
Net Zero Source Energy
Net Zero Emissions
Net Zero Energy Cost

Boundaries and metrics

ZEB:A – ZEB:D

The Definition used WILL impact the ZEB design strategies!


National Renewable Energy Laboratory
Innovation for Our Energy Future

Zero Energy Buildings:
A Critical Look at the Definition

Preprint

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June 2006

This rendering shows the proposed orientation of the National Renewable Energy Laboratory Research Support Facilities.

Getting to Net Zero

By Drury Crawley, Ph.D., Member ASHRAE; **Shanti Pless,** Associate Member ASHRAE; and **Paul Torcellini, Ph.D., P.E.,** Member ASHRAE

As the futurist Stewart Brand observed, "Every building is a forecast. Every forecast is wrong." Making forecasts progressively *less* wrong over time—specifically, forecasts about high-performance buildings—is the purpose of the U.S. Department of Energy's (DOE) Zero Energy Buildings Database. The intent of this article is to provide an overview of the DOE's efforts toward realizing cost-effective net zero energy buildings (NZEBs).

The vision of NZEBs is compelling. These highly energy-efficient buildings will use, over the course of a year, renewable technology to produce as much energy as they consume from the grid. Building owners and tenants stand to realize attractive returns on their NZEB investments while reducing carbon footprints. And, while today's buildings are our nation's highest energy-consuming and carbon-emitting sector, with NZEBs, our nation can gain a network of clean domestic energy assets.

Yet, how realistic is this vision? How close do NZEBs come to realizing their design goals? How much does it cost to design and build a net zero energy building? Thanks to data being provided voluntarily by building owners in the Zero Energy Buildings Database, we now have some early insight into these questions and into the drivers of net zero energy performance.

Just as important, we now have an influential community of industry leaders who are committed to pushing the boundaries of building performance and sharing the results. As part of the Net-Zero Energy Commercial Building Initiative, authorized by Congress in the Energy

About the Authors

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ZEBs are Here!

http://www.eere.energy.gov/buildings/commercial_initiative/zero_energy_projects.html







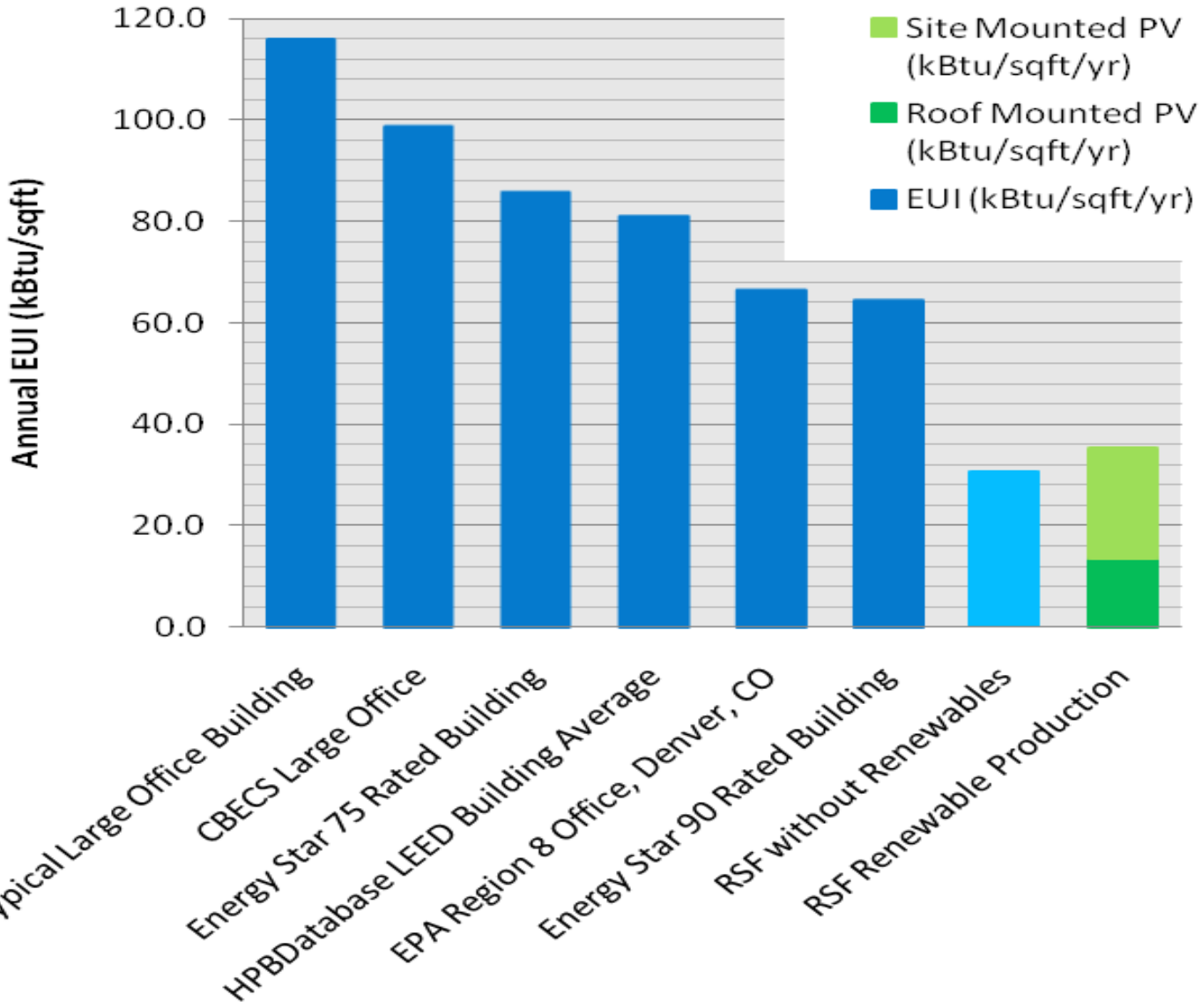
DOE/NREL Research Support Facility (RSF)


RSF Project Site

DOE/NREL RSF: Project Goals

- 800 people in DOE office space on NREL's campus
- 220,000 ft^2
- Design/Build Process with required energy goals
  - 25 kBtu/ft^2
  - 50% energy savings
  - LEED Platinum
- Replicable
  - process
  - technologies
  - cost
- Site, source, carbon, cost ZEB:B
  - Includes plugs loads and datacenter
- Firm fixed price of ~$64 million
  - $259/$ft^2$ construction cost
- Open first phase June 10, 2010

Site Energy Use Intensity - Office Buildings



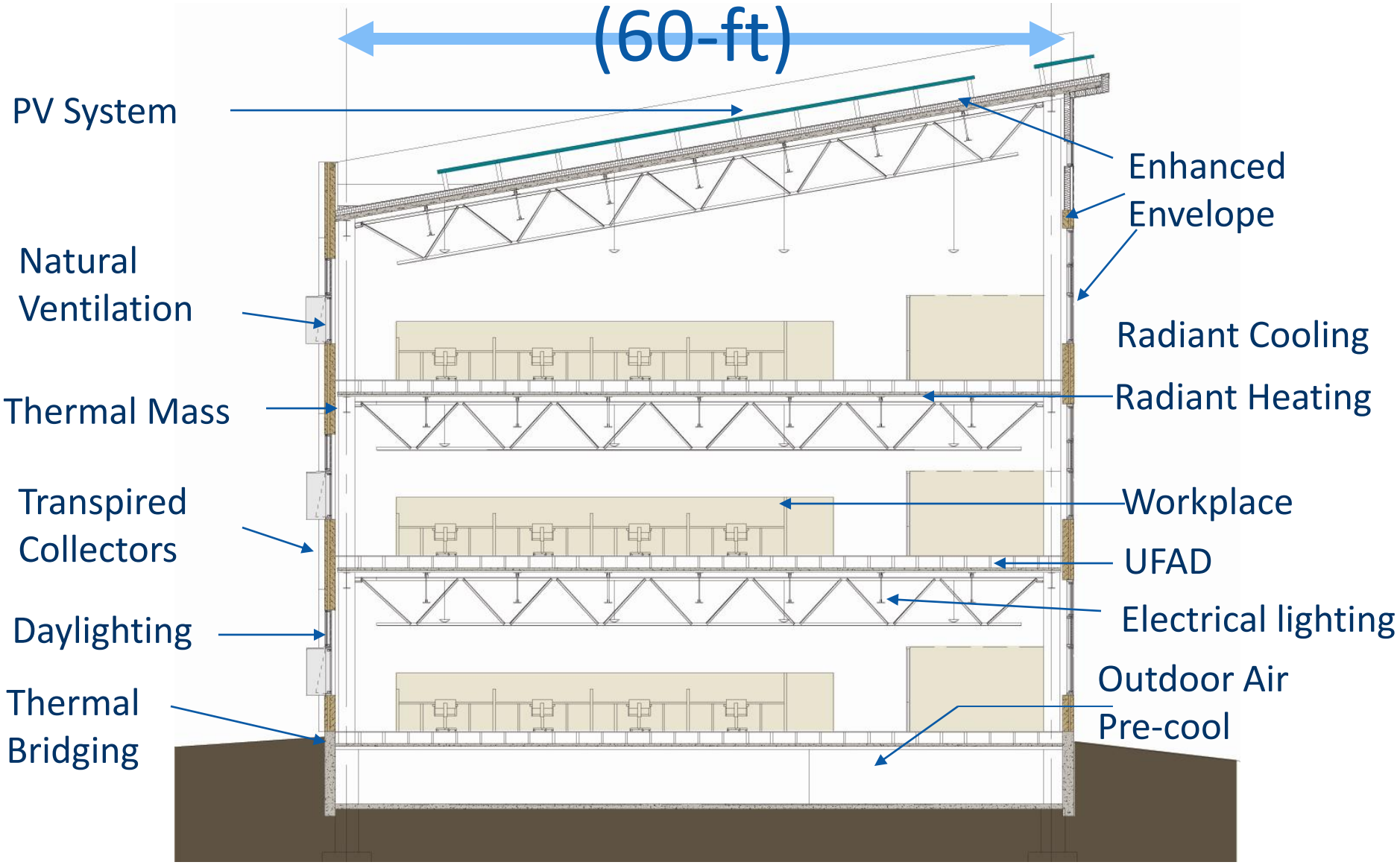
DOE/NREL Research Support Facility :
Site, Source, Cost, Emissions ZEB:B

Design Strategies for ZEB…

- Maximize space efficiency
- Envelope and orientation to reduce loads
  - Well insulated roofs, walls, floors, windows (with shading)
- Envelope and orientation to meet loads
  - Daylighting
  - Passive solar heating, Trombe walls
  - Natural ventilation
- Lighting design to match daylighting
- Plug loads
  - Design vs. owner loads
- Climate specific HVAC designed for the remaining loads
- Commissioning (making sure the building works)
- Metering and evaluation
- Make it simple

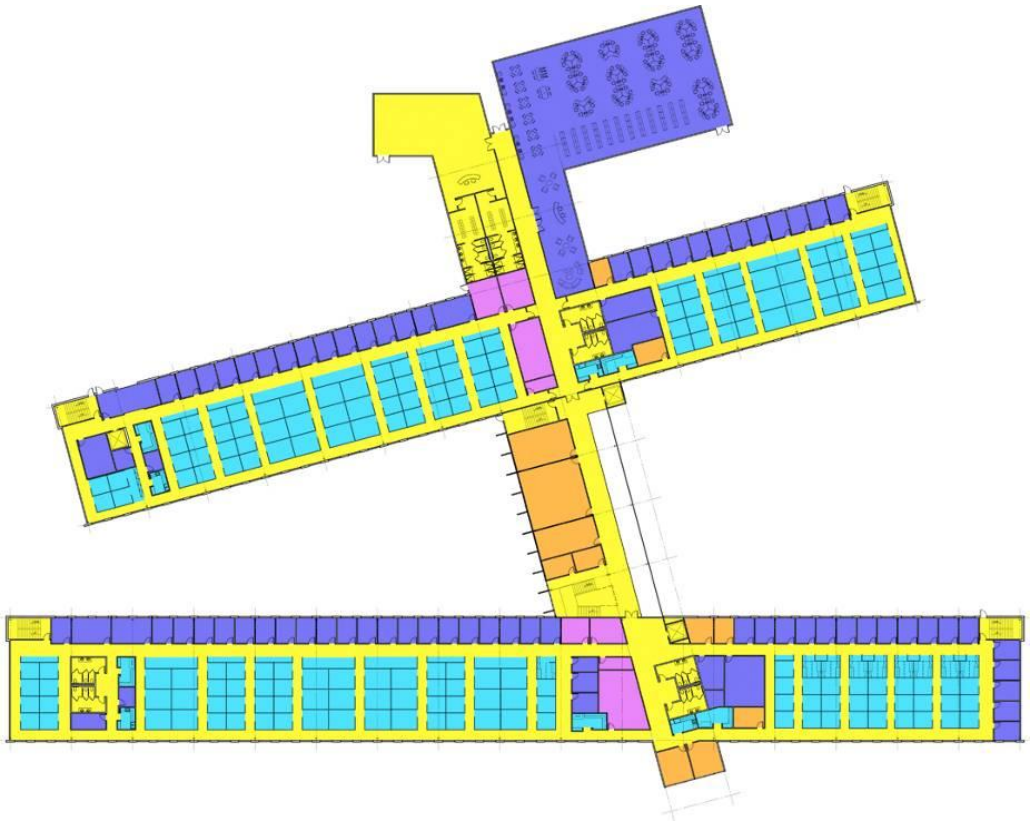
- Site specific renewable generation
  - within footprint, site, off-site
- Small amounts of RECs

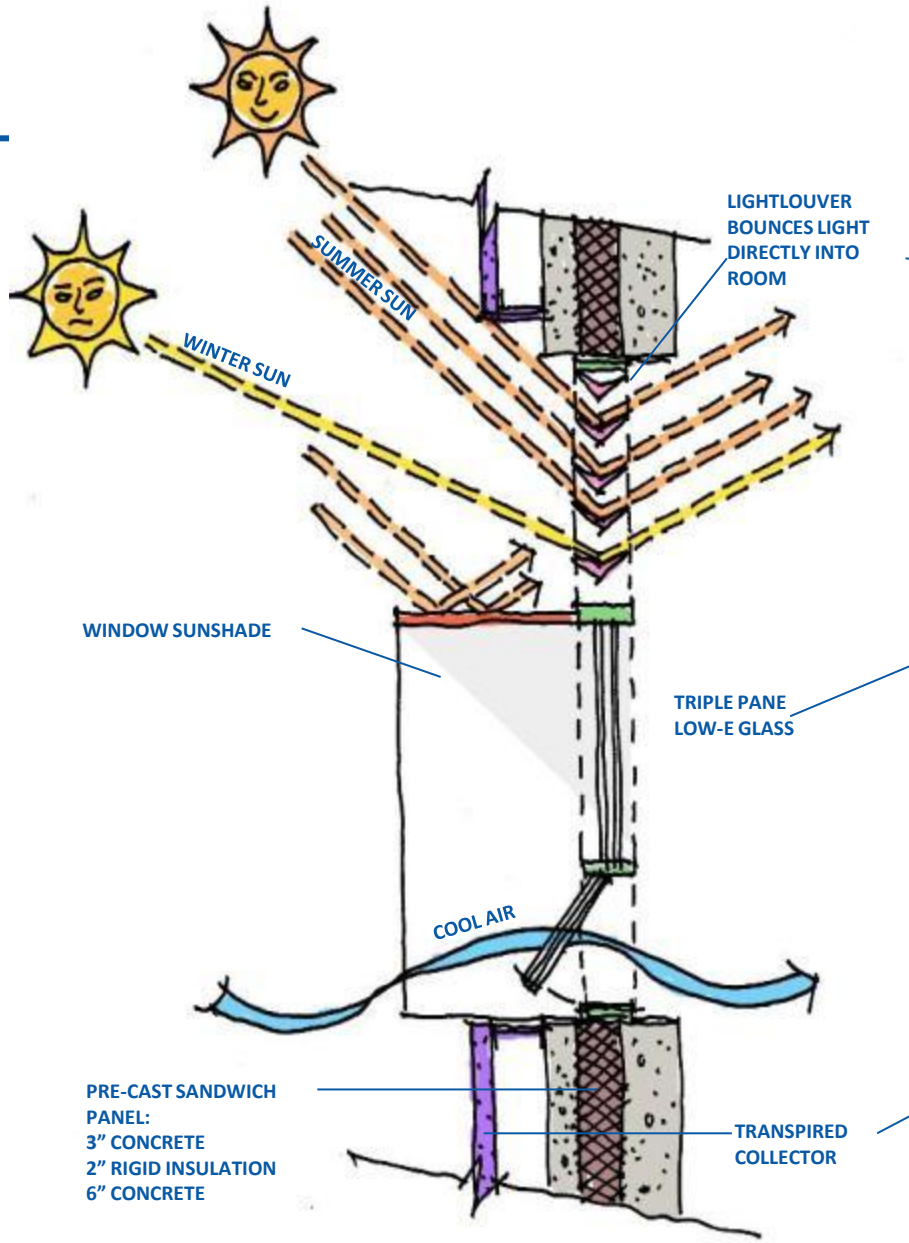
The Section

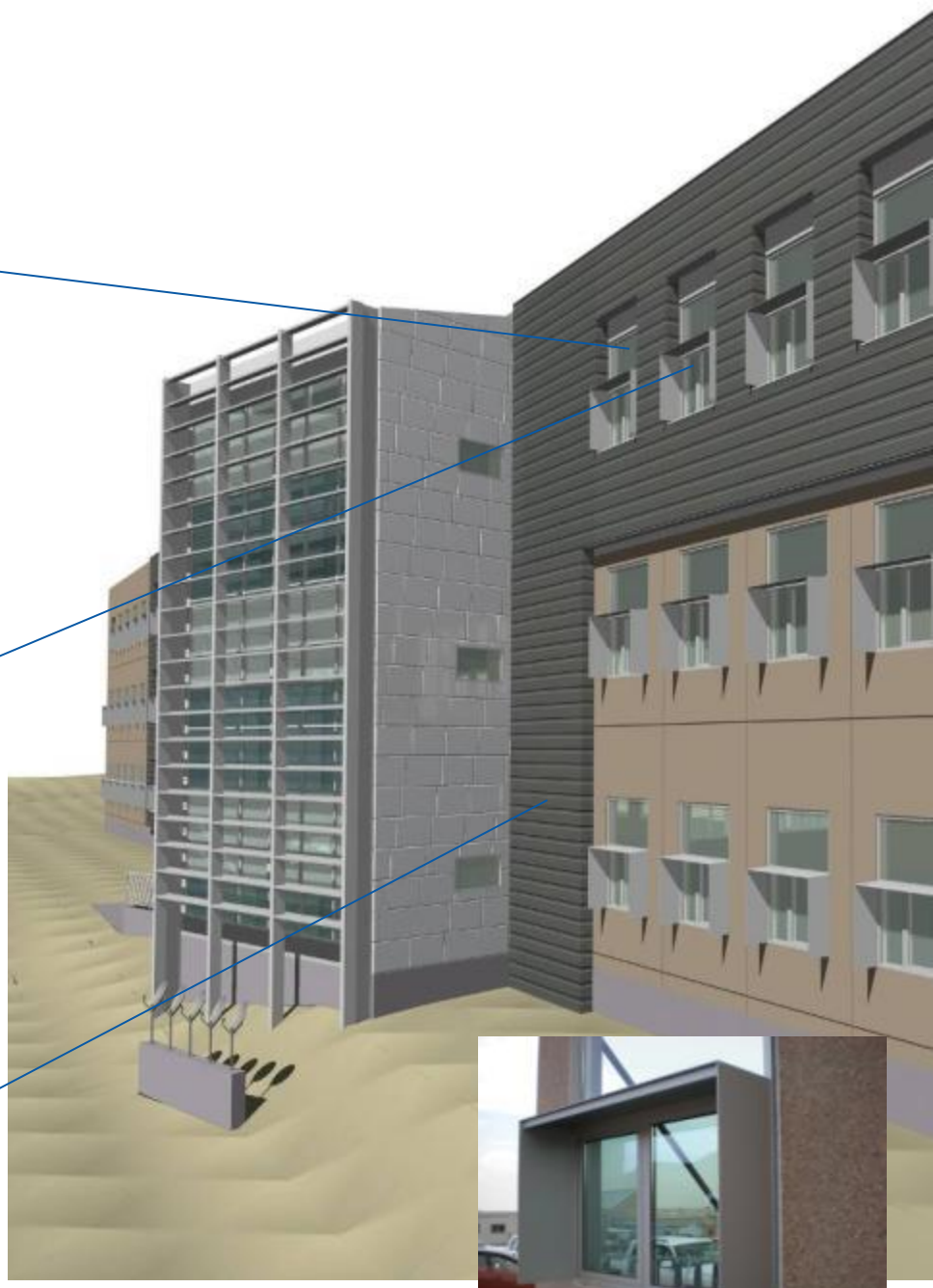

(60-ft)
PV System
Natural Ventilation
Thermal Mass
Transpired Collectors
Daylighting
Thermal Bridging
Enhanced Envelope
Radiant Cooling
Radiant Heating
Workplace
UFAD
Electrical lighting
Outdoor Air Pre-cool

Office Space of the Future

Critical to make daylighting and natural ventilation work



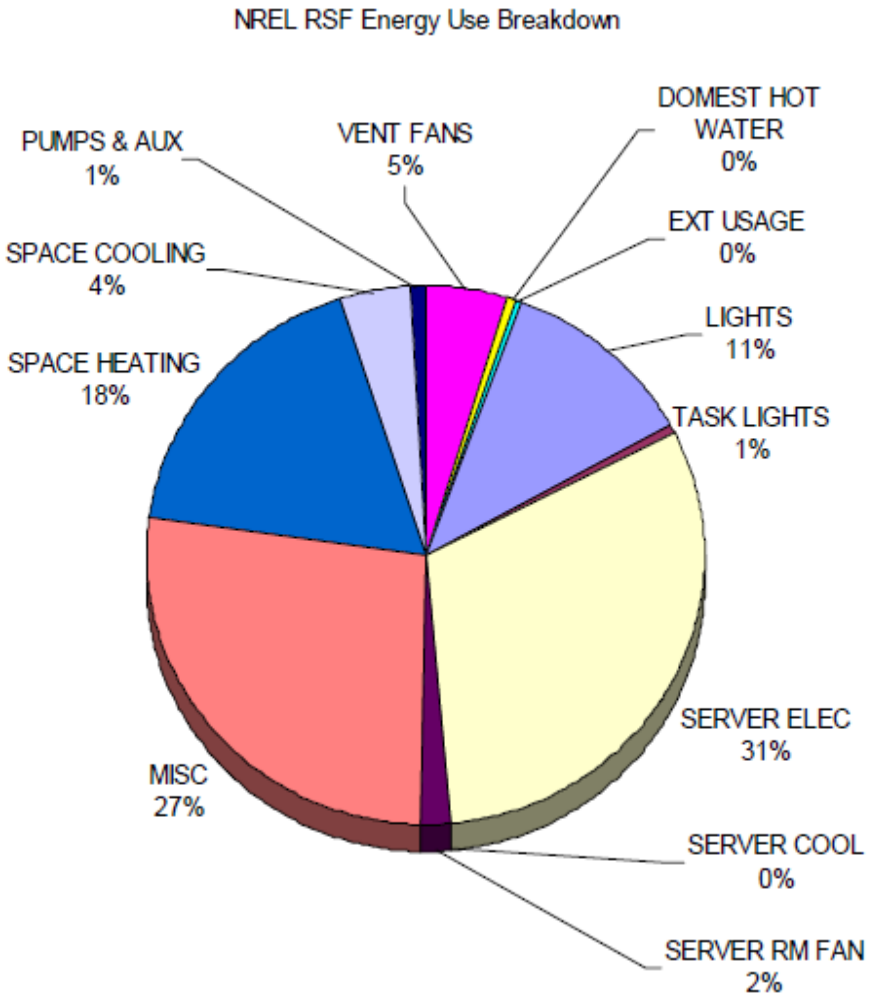

LIGHTLOUVER
BOUNCES LIGHT
DIRECTLY INTO
ROOM
SUMMER SUN
WINTER SUN
WINDOW SUNSHADE
TRIPLE PANE
LOW-E GLASS
COOL AIR
PRE-CAST SANDWICH
PANEL:
3" CONCRETE
2" RIGID INSULATION
6" CONCRETE
TRANSPIRED
COLLECTOR

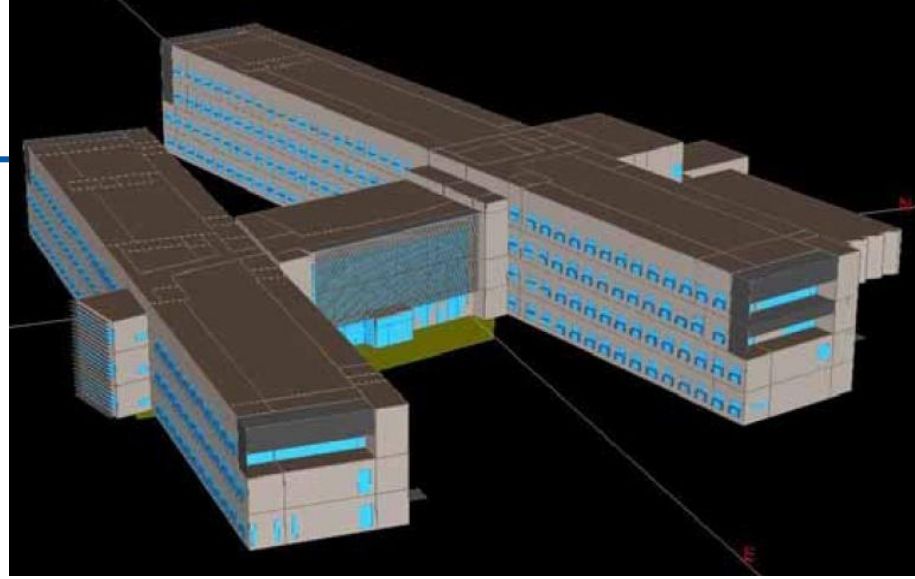


Fully Daylit with Integrated Electrical Lighting

- 0.63 W/ft^2 for 30 fc at workstation
- Manual on, manual off with vacancy sensors and local dimming controls in all daylit zones
- Run dark at night, including emergency lighting
- Super T-8s, CFLs, LEDs
- Interiors integrated with daylighting

Energy Modeling



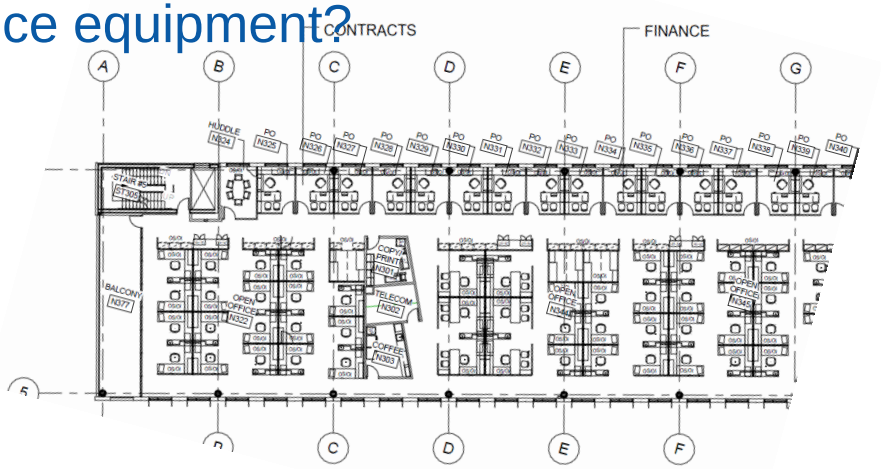


End Use	kBtu/ft2
Lights	3.85
Task Lights	0.19
Data Center	10.60
Data Center Cooling	0.01
Data Center Fans	0.55
Office Plug Loads	9.16
Space Heating	6.11
Space Cooling	1.42
Pumps	0.27
Ventilation Fans	1.61
Domestic Hot Water	0.13
Exterior Lights	0.12

Plug and Process Load Opportunities:

Design Team Opportunities

- How can space efficiency reduce office equipment?
  - Maximize use of commons spaces
    - Copy rooms
    - Break rooms
- Design to use stairs
  - Regenerative elevators
    - Slower is ok
- Minimize distribution transformers
- Exhaust transfer air for cooling of network/switch rooms
- Opportunities to turn off parasitic office equipment
  - Vampire load sensor power strips
  - Building user's manual for occupants
- Integrated datacenter cooling
  - Air side economizer
  - Evaporative cooling
  - Waste heat recovery
  - PUE 1.1



Plug and Process Load Opportunities:

Owner Opportunities

- Document current space efficiency and plug load profiles
- Multifunction Devices
  - 75% less printers
- Workstation
  - Laptops, VOIP 2 W phones, 6 W LED task lights
- Efficiency datacenter operations
  - Blade servers with virtualization
  - ASHRAE temperature Guidelines
  - Fully contained hot aisle
- All the other “STUFF”
  - EnergyStar only a starting point
  - Hand operated compact shelving
  - Minimize individual stuff
  - Question operations!
- Turn the building OFF

Workstation Type	Power	Savings
Standard PC	400w	0%
Energy Star PC	300w	25%
Laptop	60w	85%
Thin Client	35w	91%

Living in a ZEB: Every Watt Counts

- Whole building energy use = 283 Watts continuous per occupant
  - 4-5 incandescent light bulbs per occupant continuous
  - $8500 of PV per occupant
- For every 1 watt continuous we save, we avoid $33 of PV capital
- Every watt counts!
- Building User's Manual
  - Light switches
  - Operable windows
  - Computer standby

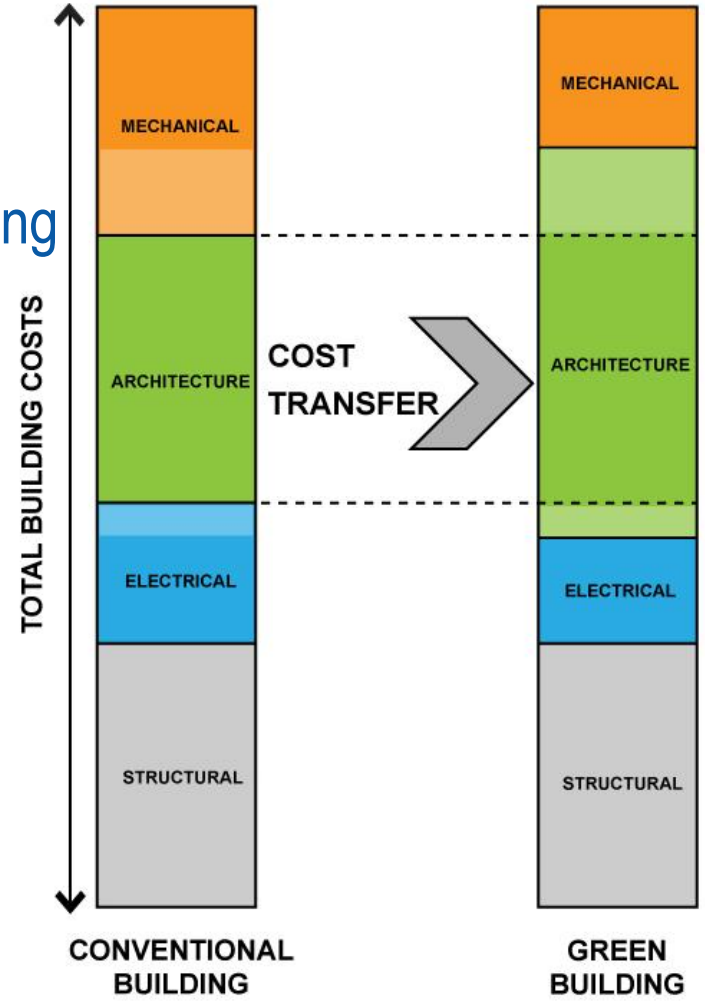
Replicable - Cost

- $259/ft^2 construction costs for site, infrastructure, and building
  - Includes interiors, furniture, and cabling
  - Does not include PV
- Third party owned PPA PV
  - $34/ft^2 or 12% additional cost (~300/ft^2) if purchased all PV without tax breaks or subsidies (at $5/watt)
- Fixed firm price with required energy goals in Design-Build contract
- Integrated architecture and envelope as efficiency measures
- Simple and commercial viable
  - No unique technologies required
  - Modular precast wall panels with minimal finishes
  - Optimized glazing area
  - Repeatable office floorplate with demountable interior walls
- Comparable cost with other institutional office buildings in the region

Integrated Design Cost Transfer

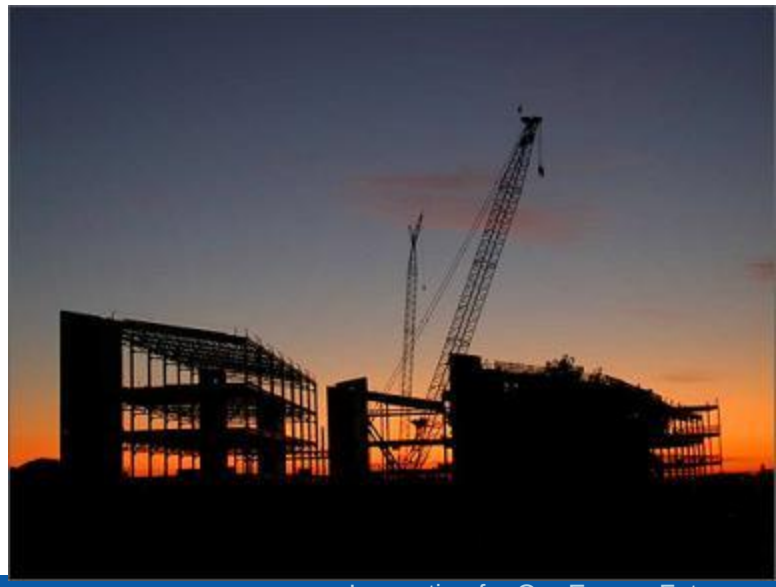
Transfer costs from mechanical and electrical systems to building architecture

- Total cost same
- Mechanical/Electrical costs less
- Invest in Architecture, Design, and modeling
- Active to passive
- Fragile to robust
- Longer life
- Less cost over life
- Simpler



Ending Thoughts

- Large Scale Net-Zero is Possible
- Zero takes a coordinated effort with the owner (and all user groups), architect, builder, and the engineering
- The little things make the difference in getting to zero
  - Anything x 824 is significant
  - Thermal breaks
  - 2 W/phone!
- The owner needs to require measurable energy goals and communicate these to the design team
  - $ incentive helps too
- The solution is not bigger supplies
  - 50-70% savings needed
- Every design and operations decision has an energy impact!



A Larger Net-Zero Energy Vision

Questions and Thanks!

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